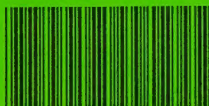


INSTRUCTION MANUAL



MP MASTER



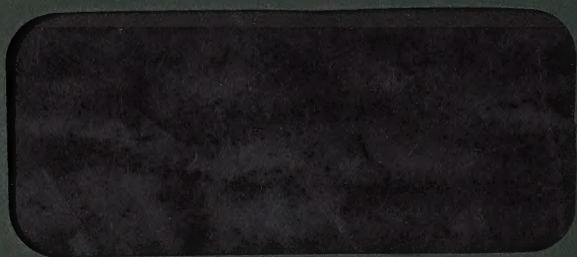
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RANK CINTEL

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DELAYED PULSE AND
SWEEP GENERATOR
CAT.NO. 3352

(Double Pulse Model)

Handbook No. 337
Third Edition

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INTRODUCTION

This instrument has been designed to provide the following facilities:

- (a) A pre pulse of fixed width and amplitude.
- (b) The main pulse of variable width, amplitude and polarity, delayed with respect to the pre pulse by a variable time.
- (c) A negative going sawtooth sweep coinciding with the main pulse.
- (d) Cable formed pulses coinciding in time with the leading and trailing edges of the main pulse.

The master waveform is derived from a multivibrator, the output of which is continuously variable from 1c/s to 1Mc/s , provision being made to enable this circuit to be synchronized to an external source when accuracies better than $\pm 5\%$ are required. Arrangements are also made to enable the multivibrator circuit to be triggered when this facility is required. In this case a single pulse can be obtained by operating the push button provided for this purpose. Associated with the multivibrator circuit are the COARSE and FINE PERIOD controls, the latter serves also as a trigger control when this circuit is used in the triggered condition.

The master waveform generated by the multivibrator is fed to the pre pulse output stage which produces positive going pulses of fixed width and amplitude at the

PRE PULSE output socket and negative going pulses for the variable delay flip flop. This flip flop produces pulses at the same repetition rate as the multivibrator but each output pulse occurs some time after the initiation pulse, the time delay between the pre-pulse and the output of this circuit being adjustable by the calibrated COARSE and FINE DELAY controls. Delayed positive going pulses obtained from the flip flop are fed to another flip flop which produces pulses whose width can be varied by means of the calibrated COARSE and FINE WIDTH controls. These pulses are then fed to an amplifier clipper the output of which is in turn fed to the sawtooth generator and to the output stage.

The output stage produces at the output terminal positive or negative pulses continuously variable over a range of from approximately 1.5V to 50V, provision being made to enable internal or external termination to be employed. Cable formed pulses of 40m μ sec width can also be selected by the output switch.

When the function switch is set for double pulse operation the variable width flip flop receives the pre pulse as well as a delayed pulse so that the first output pulse coincides with the pre-pulse and the second coincides with the delayed pulse.

CIRCUIT DESCRIPTION

Fig. 1 shows the circuit of the Waveform Generator (top unit) and Fig. 2 shows the circuit of the output stage. Stabilized d.c. supplies and unstabilized heater voltages for all valves in the equipment are derived from a power pack contained in the lower unit.

Multivibrator

V2, V3 and the associated components form a free running multivibrator, the frequency of which can be varied over a range of 1c/s to 1Mc/s , the controls being calibrated in time to simplify the use of the variable delay and pulse width facilities and because the period is a linear function of VR2. The output of this circuit appears at V3 anode and due to L3, sharp pulses appear across this choke. MR1 is included across L3 to prevent ringing and at the same time it removes most of the negative going excursions produced due to the differentiating action of the anode load.

When the COARSE PERIOD control is rotated fully clockwise the multivibrator is transformed into a Schmitt trigger by introducing direct coupling between the two valves and by returning VR2 to the junction of R91 and R24. In this case, the setting of the FINE PERIOD control VR2 determines which of the two valves conducts; when rotated fully clockwise V3 cuts off and in the fully anti-clockwise position V3 conducts. Since the circuit produces an output pulse only when V3 is changed from the conducting to the non-conducting state, for single shot work the FINE PERIOD control should be clockwise so that the output pulse coincides with the pressing of

the SINGLE SHOT button. With this control set fully anti-clockwise an output pulse will be produced on releasing the button.

Sync. Amplifier

This circuit which consists of the two sections of V1 and the associated components enables the multivibrator (or trigger) circuit to be synchronized or triggered as required by comparatively low amplitude waveforms. Amplified sync or trigger waveforms appearing across R3 are fed to V2 grid via cathode follower V1b this valve being employed to reduce feedback between grid and anode of V2. S4 is included for single shot work and when operated a positive going pulse appears at V2 grid. If VR2 is set fully clockwise, the output will be produced on pressing the button.

Pre Pulse Output Stage

V4 is normally held beyond its cut off point and therefore conduction in this stage occurs only during positive going excursions. Thus negative and positive going pulses appear at the anode and cathode respectively for every positive pulse fed to the grid. The negative pulses appearing across R34 are used to initiate the variable delay flip-flop. For double pulse operation S5 should be set to 'Double Pulse' so that the variable width flip flop produces a double pulse output.

Variable Delay Flip Flop

In this circuit V5 is normally conducting and V6 is cut off, thus on receiving a negative going pulse at its

grid V5 cuts off and V6 conducts. The two valves now remain in their second condition for a period depending on the time constant of the C-R coupling between the two valves. Due to the network in the anode of V6 there can be no output from this circuit during this change-over action until the circuit triggers back into its initial condition. On assuming its initial condition a positive going delayed pulse appears across L6.

The two sections of V7 comprise a low impedance clamping circuit the purpose of which is to provide a high aiming potential for the coupling capacitor discharge. This has the effect of reducing jitter and of making the timing period largely independent of the parameters of the valves involved in the trigger circuit. In addition the circuit provides a low impedance path through which the coupling capacitor can charge so that the flip flop assumes a state of readiness shortly after delivering a delayed pulse.

Variable Width Flip Flop

This circuit which is initiated into operation by the delayed positive going pulses is similar to the variable delay flip flop but in this case V8 is normally cut off while V9 conducts and the circuit provides rectangular waveforms. The low impedance clamping circuit consisting of the two sections of V10 functions in the same manner as described above. When S5 is set for double pulse operation, the flip flop triggers on the arrival of a pre pulse and then on the arrival of the delayed pulse so that it gives two almost identical waveforms.

Positive Amplifier Clipper

The purpose of V1 is to increase the rate of rise of

the variable width flip flop output. Normally this valve is cut off and it bottoms on receiving a positive going waveform at its grid. During the period when this valve is bottomed C1 acquires a charge due to grid current which discharges through MR1 during the inter-pulse period. The negative going output of this stage is direct coupled to the negative clipper stage V4 and to V2, the latter being associated with the sweep circuit and its function is described in that paragraph dealing with this circuit.

Negative Clipper

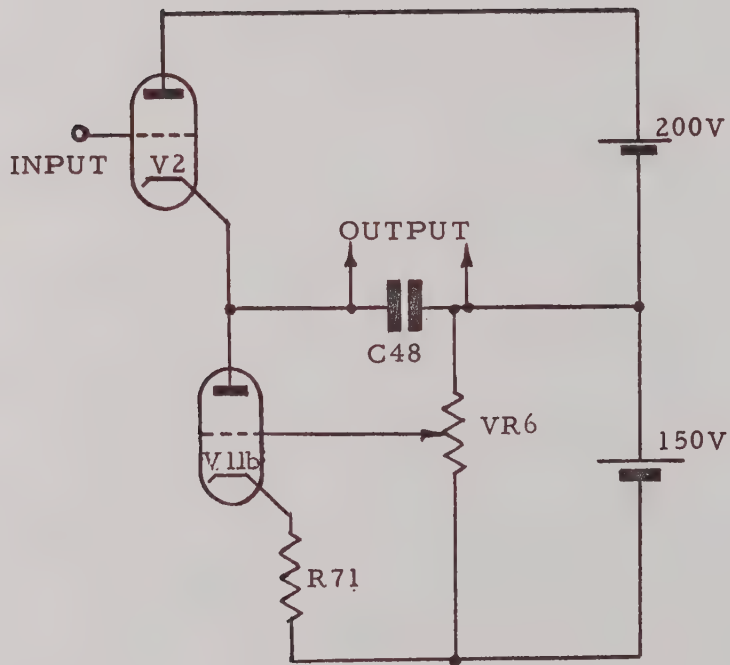
V4 is normally heavily conducting so that in this stage clipping occurs when the valve is driven beyond cut-off. The amplitude of the positive going waveform appearing at the anode of this valve is varied by controlling the zero bias current, this being achieved by varying V3a grid potential and hence the screen potential of V4. Cathode follower V3a is included to prevent loading on VR4a, thus ensuring that V4 output varies linearly with rotation of the FINE OUTPUT control. V3b is employed to provide a high differential resistance and therefore negligible attenuation in the direct coupling between V4 and V5, this being due to the high value of R37 which makes V3b appear to be a resistance of approximately $5\text{M}\Omega$. At the same time V3b maintains the interpulse period potential at V5 grid nearly constant for any setting of VR4. When the two gang control VR4 is rotated clockwise V4 screen potential increases and the d.c. anode potential decreases while V3b grid potential decreases and its anode potential increases. Thus, with the preset controls associated with this circuit correctly adjusted, adjustment of VR4 will vary the amplitude of this signal without affecting the d.c. conditions of V5.

Output Stage

Positive or negative going output, internally or externally terminated can be obtained from the output stage V5 as required. Positive going output is taken from the cathode relative to the 0V line and negative going output is taken from the anode relative to the 200V line. The 0V line is directly earthed when positive going output is selected, thus that part of the waveform corresponding with the interpulse period will be at earth potential. The neon lamp N1 is included to provide a visual indication of incorrect termination when S3 and S1 are set to obtain a negative going externally terminated output. In this case V5 anode current flows through the external resistor connected between the pulse output socket or terminal and earth; consequently if this resistor is too high, damage to V5 might result due to its drawing heavy screen current. If this resistor is too high or open circuited the voltage drop across R38 and N1 will be sufficient to cause the neon to flash at regular intervals, the rate of flashing being dependent on the value of the load and the output mark/space ratio. When S1 is set for a positive going output, the neon lamp will not - and need not - indicate incorrect terminations as the external resistor will be in series with V5 cathode.

Sweep Circuit

The diagram overleaf is a simplified arrangement of the sweep circuit which comprises the two sections of V11 (Top Unit) and V2 (Bottom Unit); for simplicity however, the cathode follower V11a (Top Unit) is omitted. Referring to



Simplified Circuit
of
Sawtooth Generator

the simplified diagram, it can be seen that the charging capacitor is connected so that it can charge via the low impedance valve V2 and discharge via the high impedance valve V11b. V2 is normally conducting and on receiving a negative going waveform at this grid, this valve becomes cut off for a period equal to the duration of the waveform. C48 now starts discharging through V11b at a rate depending on the setting of VR6. Since constant current must flow through V11b due to the high value of R71, the rate of discharge continues to occur linearly until V2 is allowed to conduct again. When V2 conducts again C48 charges rapidly due to the low impedance path offered by V2 and the circuit remains in this condition until the arrival of a further switching waveform at V2 grid. From the above explanation it is clear that the amplitude of the negative going sawtooth depends on the width of the input waveform as well as the setting of VR6. Referring to Fig.1 it can be seen that the sawtooth waveform is fed to the output terminals via cathode follower V11a. This valve is brought into circuit only when the COARSE OUTPUT switch is set to give a positive going output. This is done to prevent a high potential from being present at the white terminal when the switch is set to give a negative going output.

Power Pack

Winding W-X-Y and MR2-MR3* form a full wave rectifying circuit which provides across C23 about +320V relative to the 0V line, and winding X-Y together with MR4* form a half-wave rectifying circuit which produces across C25 about -320V relative to the 0V line. V7 stabilizes the negative supply at 150V; this stabilized supply serves also as a voltage reference for the series regulator circuit.

- * On instruments with serial numbers before 285, a full wave diode, (V9 type GZ33) was used in place of MR2-MR3; a half wave diode (V10 type R17) was used for MR4.

consisting of V8, V6 and their associated components. The two sections of V6 form a starved cascode amplifier, the output of which is d.c. coupled to the grids of the series regulator V8, this valve being shunted by R68 to reduce the amount of current flowing through it.

OPERATIONAL NOTES

Owing to the arrangement, markings and calibration of the operator's controls the instrument is quite simple to use, however there are a few points which must be observed when using the equipment; these are tabulated below.

Terminations

When the internal terminations are used, a cable of the correct impedance must be used especially if the cable is long, otherwise waveform distortion will result. If the cable is over 15ft long a high quality type must be used. Non-inductive potentiometers and π attenuators of the correct impedance can be used to terminate the cable, provided that these are connected directly to the cable, i.e. without extending leads.

When external terminations are used the cable must also be high of quality and have the correct impedance; alternatively the terminating resistor should have a value to suit the cable available. Connect this resistor or pad to the cable ends as explained above.

The pre-pulse output impedance is about 75Ω and that of the sweep output is about 300Ω . (See specification)

Controls

Coarse and fine controls are provided for adjustment of the period, delay and width, the fine control being effectively a multiplier of the coarse control. When using the fine controls care should be taken to set the pointer

exactly on the mark, otherwise the accuracy will be outside 5%. The delay period controls should not be set so that the delay exceeds 75% of the pre-pulse period otherwise frequency division might result. This applies to the width controls as well. The fine control knobs including the fine output control knob should never be removed as this will upset the calibration. The calibrated output levels will be within the specified limits of accuracy when the fine output control is set exactly to the 'calibrated' position. Full anti-clockwise rotation of the fine control reduces the output by about four times.

The amplitude of the sweep output can be varied by the uncalibrated control, but adjustment of the pulse width will also vary the sweep amplitude, giving effectively constant writing speed irrespective of width. The sawtooth waveform has a duration equal to the width of the main output pulse. Note that the sawtooth waveform is only available when the COARSE OUTPUT switch is set to one of the positive output positions.

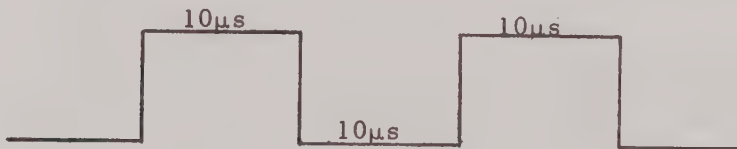
When the instrument is being used in the free running condition, pick up via the sync terminal might cause slight inaccuracy on the higher frequency ranges, therefore in this case it is desirable to turn the sync control fully anti-clockwise.

Double Pulse Operation

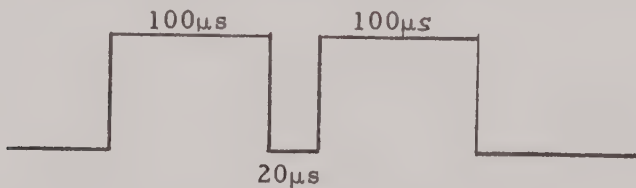
Due to the fact that the shapes of the pre pulse and the delayed pulse are somewhat dissimilar, the width of the two output pulses will be slightly different, the first being about $0.05\mu\text{sec}$ wider than the second. Since the difference is quite small, it is usually unimportant in

practice; it is only appreciable when the $0.1\mu\text{sec}$ coarse width range is being used.

As shown below, a minimum period must be allowed between the trailing and leading edges of the pre pulse and the delayed output pulses to allow the variable width generator to recover. If a shorter period than that specified is used, the second pulse begins to narrow until it finally disappears and the variable width generator begins to divide. With the fine width control set at minimum, the recovery period is approximately equal to the nominal coarse width setting; with the fine width control at maximum, the minimum recovery period is $10\mu\text{secs}$.



If the fine width is set to maximum, the delay can be adjusted to obtain an interpulse period as short as $20\mu\text{secs}$ before the second pulse begins to narrow.



Thus in the first case, the mark/space/mark ratio is $1:1:1$ and in the second case the ratio is $5:1:5$.

The sweep circuit is fed from the variable width generator and therefore produces a double sweep coincident with positive double pulse outputs.

SPECIFICATION

Period

Continuously variable from $1\mu\text{sec}$ to 1sec in six overlapping decade ranges with fine control. This corresponds to a frequency range 1c/s to 1Mc/s . The variable control scale is approximately linear and accuracy of calibration is to within $\pm 5\%$.

Pre-Pulse

Fixed width: Less than $0.1\mu\text{sec}$
Fixed amplitude: 6V peak at 75Ω .
Positive going.

Delay

The maximum delay obtainable without frequency division is about 75% of the pre-pulse period. The scale is approximately linear and the calibration is accurate to within 5% .

Main Pulse

The main output pulse, which is d.c. coupled can be varied in width, amplitude and polarity as follows:

Width: The maximum width obtainable without frequency division is about 75% of the pre-pulse period.

Amplitude: The output amplitude and impedance depends on the setting of the COARSE OUTPUT switch. The FINE control is calibrated in one position only to coincide with

the maximum output per range and gives an attenuation of approximately 4 : 1 of each maximum.

Amplitude	Impedance	Rise Time
5V max.	75 Ω	∇ 25 μ sec
10V max.	150 Ω	∇ 25 μ sec
25V max.	600 Ω	∇ 40 μ sec
50V max.	1000 Ω	∇ 50 μ sec

Polarity: Positive or negative going with respect to earth.

Accuracy: Calibration accurate to within $\pm 5\%$ on all ranges except the 50V range which is within $\pm 10\%$.

Sweep

The sweep waveform is a d.c. coupled negative going sawtooth with approximate respect to earth having the same width as the main pulse and same delay as the pre-pulse. It is available when using a positive going main output pulse only.

The amplitude is about 12V peak at maximum width and maximum amplitudes of less than 12V will pertain depending upon the width of the main pulse. The output impedance is approximately 300 Ω but to ensure satisfactory operation, the load impedance should not be less than 10k Ω .

The amplitude is independent of frequency and linearity is maintained to within $\pm 5\%$.

Cable Pulse In this condition the main output pulse is injected into a pure line short-circuited at the far end and the reflection used to cancel a large proportion of the main pulse, thus giving a very narrow output pulse. One positive and one negative going pulse is produced coinciding with the leading and trailing edges of the main pulse. These pulses which are $40\text{m}\mu\text{sec}$ wide have a maximum amplitude of 2V in 75Ω and rise time $\approx 15\text{m}\mu\text{sec}$.

Sync/Trigger The generator is capable of being synchronized or triggered by almost any externally applied waveform. Minimum levels for a sinewave are:

Sync: 0.5V peak to peak.
Trigger: 1.0V peak to peak. 2Mc/s max.

Voltage 110-120V, 200-250V in 5V steps.
40 to 60c/s.

Consumption 200V.A.

Valves Used

5	Mullard	ECC81
1	Mullard	ECC83
5	Mullard	E180F
6	Mullard	EL322
1	Mullard	6080
1	Mullard	150B2

Power Rectifiers

3	Plessey	80AS
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SETTING UP

To set up the various preset controls in this instrument, a wide range calibrated oscilloscope having a better accuracy than that of the instrument is required. In the factory setting-up is carried out with the aid of a 'Tektronix' oscilloscope Type 545 using a plug-in unit Type 53/54K. A signal generator with an accurately calibrated attenuator and a high impedance sub standard voltmeter are also required. All tests should be done with the two units removed from the case and reconnected together. During setting up care must be taken to keep away from the rotating fan; this could be removed from the motor shaft if required. Note also that either the positive or negative h.t. line may be at earth depending on the setting of the COARSE output; think twice before connecting test gear to the instrument. Setting up is carried out with the instrument switched to 'single pulse'.

Waveform Generator

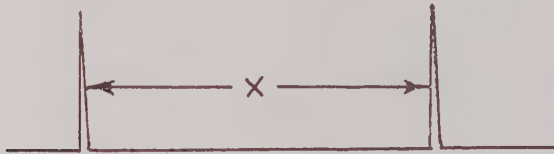
Drg. No. 31E/3600

The various stages in this unit are set up in the following sequence: Multivibrator; Delay Flip Flop; Variable Width Flip Flop; Sweep Circuit. If say a valve associated with the variable delay Flip Flop is replaced, it will be only necessary to carry out the procedure in that sub section dealing with that circuit.

1. Multivibrator

- (a) With the instrument set for 'SINGLE PULSE' set COARSE OUTPUT switch to +10V. FINE OUTPUT to calibrated, TERMINATION to INTL., SYNC. fully anti-clockwise, COARSE PERIOD to 1 μ sec. FINE PERIOD to 10 and switch ON.

- (b) Connect oscilloscope input to PRE-PULSE OUTPUT socket and check that the following waveform appears on the screen.



Pulse width must be less than $0.1\mu\text{sec}$ and amplitude greater than 6V peak into a 75Ω load.

- (c) Set COARSE PERIOD to $100\mu\text{sec}$, FINE PERIOD to '1'. COARSE DELAY to $10\mu\text{sec}$. FINE DELAY to '1'. COARSE WIDTH to $10\mu\text{sec}$. FINE WIDTH to '1'.

Connect PRE-PULSE OUTPUT to trigger input of oscilloscope and connect the OUTPUT terminals to the input of the oscilloscope. Set Oscilloscope controls to obtain a stationary waveform.

- (d) Check that the repetition rate, delay and width of this waveform can be varied by adjustment of the FINE PERIOD, DELAY and WIDTH controls and reset the FINE DELAY and WIDTH controls fully anti-clockwise, set FINE PERIOD to '10'.
- (e) Adjust VR3 to make PERIOD equal to 1msec , remove knob from FINE PERIOD control and adjust FINE PERIOD spindle to make PERIOD equal to $100\mu\text{sec}$.
- (f) Replace knob carefully at '1', taking care not to rotate spindle, and tighten grub screw.

- (g) Set FINE PERIOD to '10' and if necessary adjust VR3 to obtain a period of 1msec as before.
- (h) Turn FINE PERIOD back to '1' and if period is now not 100μsec remove knob again and repeat (f).

Repeat (g) and check that period is 1msec $\pm 5\%$ then check that period is 100μsec $\pm 5\%$ with FINE control at '1'.

- (i) Set COARSE PERIOD to 10μsec. Check that the period is 10μsec $\pm 5\%$ with the FINE control at '1' and then that the period is 100μsec $\pm 5\%$ with FINE control at '10'.

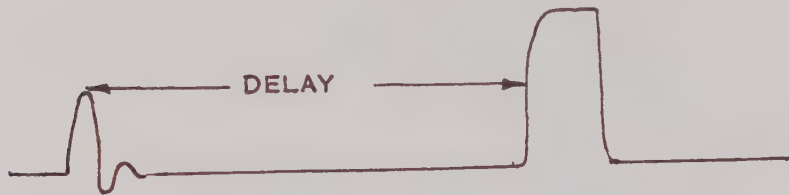
Repeat the check of FINE PERIOD control on all ranges of the COARSE PERIOD, except the 1μsec range and if it is found that one range is well within 5%, while another is outside these limits, re-adjust VR3 or the knob of the FINE PERIOD to bring all ranges within the specified limits.

- (j) Set COARSE PERIOD to 1μsec and FINE PERIOD to '10'. Set COARSE WIDTH to 0.1 and FINE WIDTH to '5'. Adjust C9 to obtain a period of 10μsec.
- (k) Set FINE PERIOD to '1' and adjust L1 to obtain a cycle period of 1μsec $\pm 5\%$.

2. Variable Delay Flip-Flop

- (a) Set CONTROLS and SWITCHES as before 1 (a)
Set FINE DELAY and WIDTH controls fully anti-clockwise and COARSE controls to 1μsec and 0.1μsec

respectively. Connect a capacitor of about 20pF between the PRE-PULSE OUTPUT and the MAIN OUTPUT terminal. Turn up oscilloscope sensitivity and check that the pre-pulse precedes the main pulse as shown below. Time delay between the two waveforms is measured from 1st peak of pre-pulse to leading edge of main pulse, at a level which corresponds to the peak amplitude of the pre-pulse.



- (b) Set COARSE PERIOD to 1msec and FINE PERIOD to '3', COARSE DELAY to 100 μ sec and FINE DELAY to '10', adjust COARSE and FINE WIDTH to obtain a main pulse of required width.
- (c) Adjust VR4 to obtain a delay time of 1msec and remove knob from FINE DELAY control.
- (d) Rotate spindle anti-clockwise to obtain a time delay of 100 μ sec, replace knob carefully at '1', taking care not to rotate spindle, and tighten grub screw.
- (e) Set FINE DELAY to '10', check that the time delay is 1msec and if necessary re-adjust VR4.

- (f) Turn FINE DELAY back to '1', check that the time delay is $100\mu\text{sec}$ and if necessary re-adjust knob again with the pointer at '1'.
- (g) If necessary repeat (e) and (f) until time delay is within $\pm 5\%$ with FINE control at '1' as well as '10'.
- (h) Set COARSE PERIOD to $100\mu\text{sec}$. FINE PERIOD to '3'. COARSE DELAY to $10\mu\text{sec}$. FINE DELAY to '10'. Set WIDTH control to obtain a duration equal to maximum delay, i.e., $100\mu\text{sec}$. Check that the accuracy of the delay is within $\pm 5\%$ with the FINE DELAY at '1' as well as at '10'.
- (i) Repeat the check of FINE DELAY CONTROL on the remaining ranges except $0.1\mu\text{sec}$. Ensure that in each case the width is equal to the delay and that the period is 30 times the delay. If it is found that one range is well within $\pm 5\%$, while another is outside these limits re-adjust VR4 or the FINE control knob to bring all ranges within the specified limits.
- (j) Set the COARSE PERIOD, DELAY and WIDTH to 1, 0.1 and $0.1\mu\text{sec}$ respectively. Leave the FINE PERIOD at '3', set FINE DELAY to '10' and FINE WIDTH to '1'.
- (k) Adjust C25 to obtain a delay time of $1\mu\text{sec}$. Set FINE DELAY to '1' and check that delay is $0.1\mu\text{sec} \pm 5\%$ of full scale. On this range non linearity of the fine control is within the limits $\pm 5\%$ of full scale due to the significance of the inherent 30ns delay of the main pulse on the pre-pulse.

3. Variable Width Flip Flop

- (a) Set the controls in the OUTPUT stage as in 1(a) and the Waveform Generator controls as follows: PERIOD COARSE and FINE to 1msec and '3' respectively. WIDTH COARSE and FINE to 10 μ sec and '10' respectively.
- (b) Connect oscilloscope to the OUTPUT terminals and adjust VR7 to obtain main pulse width of 100 μ sec.
- (c) Remove knob from FINE control and rotate spindle anti-clockwise to obtain a pulse width of 10 μ sec. Replace knob carefully on spindle without rotating it so that the pointer indicates '1' and tighten grub screw.
- (d) Check that with the FINE control at '10' the pulse width is 100 μ sec; adjust VR7 if necessary.
- (e) Turn back FINE WIDTH to '1' and if necessary repeat (c).
- (f) Set FINE WIDTH to '10' and check that the accuracy on all ranges except 0.1 μ sec is $\pm 5\%$.

It should be noted that the PERIOD switch should be set so as to obtain a period time equal to 10 times the duration on each range of the COARSE WIDTH control setting.

- (g) Set FINE WIDTH to '1' and check that all ranges are within $\pm 5\%$.
- (h) Set PERIOD COARSE and FINE to '1' and '3' respectively. Set WIDTH COARSE and FINE to 0.1 and '10' respectively.

- (i) Adjust C40 to obtain a pulse width of $1\mu\text{sec}$. Check that with the FINE WIDTH at '1' the width is $0.1\mu\text{sec} \pm 5\%$. It may be necessary to re-adjust C40 to obtain the same degree of accuracy at both ends of the FINE WIDTH control.

4. Sweep Circuit

- (a) With the OUTPUT controls and TERMINATION switch set as 2(a), check the negative sawtooth waveform at the SWEEP OUTPUT terminals.
- (b) Check that the amplitude varies by adjustment of the SWEEP AMPLITUDE control as well as by adjustment of the WIDTH controls.
- (c) With the SWEEP AMPLITUDE fully clockwise and the FINE WIDTH at '10', the amplitude should be over 12V peak on all settings of the COARSE WIDTH control. Disconnect oscilloscope.
- (d) Feed the sawtooth to the oscilloscope in place of the internal time base generator and feed the output of a suitable Signal Generator to the oscilloscope input.
- (e) Set the oscillator frequency as required and check linearity by examining the distance between each cycle of the oscillator. It may be necessary to synchronise the instrument to the oscillator. The linearity must be better than $\pm 5\%$.

5. Sync and Trigger

- (a) Connect oscilloscope to output and set OUTPUT controls as 2(a).

- (b) Set COARSE PERIOD to TRIGGER and FINE PERIOD to '10'. Check operation of SINGLE SHOT button on all ranges of the DELAY and WIDTH controls.
- (c) Set DELAY and WIDTH controls at minimum, connect a suitable signal generator to SYNC.INPUT.
- (d) Adjust signal generator to give an output of 1Mc/s at 1V p.p. and set SYNC. at maximum.
- (e) Adjust FINE PERIOD until instrument triggers, check that the instrument triggers satisfactorily up to 2Mc/s.
- (f) Set all COARSE Controls (except OUTPUT) to minimum and adjust signal generator output to give 0.5V p.p. With SYNC. at maximum check that the instrument can be synchronised up to 2Mc/s.

POWER SUPPLY & OUTPUT STAGE Drg.No. 31E/3931

As previously explained, the two units must be removed from the case and reconnected together.

Connect to a tested Waveform Generator.

1. Power Pack

- (a) Check the interconnecting cables between the mounts.
- (b) Set the controls mentioned below as follows:-

PERIOD:	20msec	DELAY	1msec
WIDTH:	5msec	COARSE OUTPUT	+10V
		FINE OUTPUT:	CAL.

- (c) Remove the Output Valve V5.
- (d) Set mains voltage selector according to the mains voltage available.
- (e) Supply to be applied by means of a 'Variac'. Check fuses F1, F2 and Switch ON.
- (f) Check transformer voltages.

Check H.T. +line
Check H.T. -line
See list of Test Voltages

- (g) Check that 200V H.T. supply can be varied from 190 to 210V by means of VR11 and reset the control to give 200 volts.

- (h) Check that the total hum on the 200V line is less than 15mV p.p.
- (i) Vary mains input by +20V and check that the 200V line does not vary by more than $\pm 3V$.

2. V5 Grid Potential

As mentioned in the circuit description, V5 grid potential must be approximately constant on all settings of the OUTPUT switch. The oscilloscope in this case must be set up for d.c. measurements and V5 must be removed.

- (a) Set PERIOD to 10msec. DELAY to $0.1\mu\text{sec}$. WIDTH to 5msec, and FINE OUTPUT to CAL.
- (b) Connect the oscilloscope input to the junction of R.35 -R.36 and adjust PERIOD and WIDTH to obtain a square wave having a 1 : 1 mark/space ratio.
- (c) Set COARSE OUTPUT to +10V and adjust RV1 to obtain an amplitude of 21V peak.
- (d) Set COARSE OUTPUT to +25V and adjust RV2 to obtain an amplitude of 34V peak.
- (e) Set COARSE OUTPUT to +50V and adjust RV3 to obtain an amplitude of 62V peak.
- (f) Set COARSE OUTPUT to +10V and adjust RV5 to set negative end of square wave at exactly -15V.
- (g) Set FINE OUTPUT fully anti-clockwise and adjust RV10 to bring negative end of the square wave back to -15V.

- (h) Reset FINE OUTPUT to CAL and adjust RV5 again to bring negative end of square wave back to -15V.
- (i) Repeat (g) and (h) until there is no appreciable change in the negative end of square wave with FINE control at minimum and at CAL.
- (j) With the COARSE and FINE OUTPUT controls set at +25V and at CAL. adjust RV6 to bring the negative end of square wave to -15V.
- (k) Set FINE OUTPUT to minimum and adjust RV9 to bring negative end of square wave to -15V.
- (l) Repeat (j) and (k) and check as in (i).
- (m) With COARSE and FINE OUTPUT controls set at +50V and at CAL, adjust RV7 to bring negative end of square wave to -15V.
- (n) Set FINE OUTPUT to minimum and adjust RV8 to bring negative end of square wave back to -15V.
- (o) Repeat (m) and (n) and check as in (i).

Switch off and insert V5.

3. Pulse Amplitude

Before attempting the procedure below, insert the oscilloscope probe in CAL.OUT socket on the oscilloscope and if necessary adjust the probe in accordance with the instructions given in the TEKTRONIX handbook. The oscilloscope controls must be set for d.c. measurement.

- (a) Set controls as in 2(a). Set COARSE OUTPUT to +10V and FINE OUTPUT to CAL. It is important to have a 1 : 1 mark/space ratio.
- (b) Check the waveform at the output terminals and adjust C9 to obtain best waveshape.
- (c) Connect to the output terminals a high impedance substandard d.c. Voltmeter (25V F.S.D.) or better still a sub-standard microammeter, in series with a suitable resistor.
- (d) Set FINE output to CAL. and adjust RV5 to obtain a reading of 5V on the Voltmeter; this reading is the average d.c. content of the 1 : 1 square wave output.
- (e) Connect oscilloscope to the junction of R35-R36 and adjust RV1 to bring the negative end of square wave to -15V.
- (f) Adjust RV10 with the FINE OUTPUT control fully anti-clockwise to bring negative end of square wave back to -15V, then, with FINE OUTPUT at CAL, re-adjust RV5 to restore negative end of square wave back to -15V.
- (g) Repeat (f) until there is no appreciable difference in the negative end of square wave with the FINE control at minimum and at CAL.
- (h) Remove oscilloscope, set COARSE OUTPUT to +25V. FINE OUTPUT to CAL. Adjust RV6 to obtain 12.5V on the voltmeter.
- (i) Connect oscilloscope to junction of R35 - R36 again

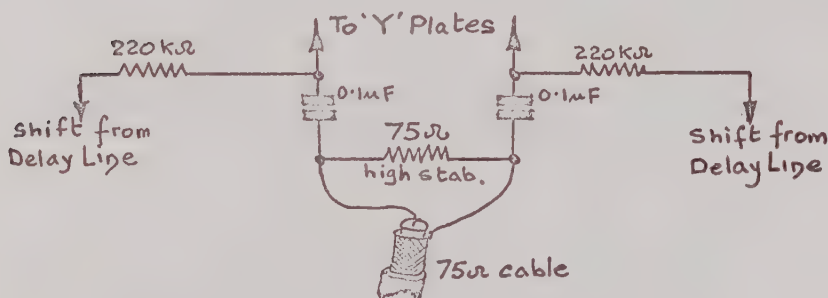
and adjust RV2 to bring negative end of square wave to -15V.

- (j) With the FINE OUTPUT control fully anti-clockwise adjust RV9 to bring negative end of square wave back to -15V, then with the FINE OUTPUT control at CAL, re-adjust negative end of square wave back to -15V - Repeat this until there is no appreciable difference in negative end of square wave, with the fine OUTPUT control at minimum and at CAL.
- (k) Remove oscilloscope, set COARSE OUTPUT to +50V. FINE OUTPUT to CAL. Adjust RV7 to obtain 25V on the voltmeter.
- (l) Reconnect oscilloscope as in (i) and adjust RV3 to bring negative end of square wave to -15V. Set FINE OUTPUT fully anti-clockwise and adjust RV8 to restore negative end of square wave to -15V.
- (m) Re-adjust RV7 with FINE control at CAL, then RV8 with FINE control at minimum, until there is no appreciable difference in negative end of square wave at both ends of FINE OUTPUT control.
- (n) Disconnect oscilloscope and check that all ranges are within $\pm 5\%$ except the 50V and CABLE ranges; the 50V range should be within $\pm 10\%$.

4. Wave shape

Before attempting to adjust L1 and L2 to obtain the best trailing and leading edges of the waveform, the TEK-TRONIX oscilloscope must be modified as shown in the

diagram below. The components required for the modification, should be rigidly mounted on low loss material, such as 'Perspex', using the shortest possible leads between the items. The 75Ω cable must be connected directly to the ends of the terminating 75Ω resistor and the components must be located as near as possible to the delay line and the Y plate connections.



To carry out this modification, remove the left side panel of the oscilloscope and disconnect the Y plate leads from the tube. Connect two $0.01\mu\text{fd}$ capacitors to the Y plates as shown, by means of short leads and connect the two 'Y' leads removed from the tube to the free ends of the two 220K resistors, this enables the shift control to remain operative.

- (a) Set COARSE PERIOD to $10\mu\text{sec}$, FINE PERIOD to '1', DELAY to $0.3\mu\text{sec}$, WIDTH to $0.3\mu\text{sec}$. FINE OUTPUT to CALIBRATED.

- (b) Connect the 75Ω cable to the OUTPUT socket, set COARSE OUTPUT to +5V and set TERMINATION to EXTL.
- (c) Adjust L1 until overshoot just starts to appear on the trailing edge, check that the rise time of the trailing edge as measured between 10 & 90% of the amplitude is not greater than 20nsec.
- (d) Adjust L2 until overshoot just starts to appear on the leading edge, check that the slope of the leading edge, measured between 10 & 90% of the of the amplitude, is not greater than 25nsec and not less than 8nsec.
- (e) Set COARSE OUTPUT to -5V and adjust C14 until overshoot just starts to appear on the leading edge. Slopes of the leading and trailing edges should be checked as for the +5V pulse.
- (f) Set COARSE OUTPUT to CABLE. Check that the duration of the negative pulse as well as that of the positive pulse is $40\text{nsec} \pm 30\%$.

The amplitude should be at least 2V peak-to-peak and the rise time not greater than 15nsec.
- (g) Set TERMINATION to INTL. disconnect the 75Ω cable and reconnect the oscilloscope Y plate leads for normal operation. Connect oscilloscope input to the OUTPUT of the instrument.
- (h) With the COARSE OUTPUT set to +10V check that the leading edge over 10 to 90% of the amplitude is not more than 25nsec.

- (i) Set COARSE OUTPUT to +25V. Adjust L3 to obtain the best leading edge, check that the rise time, as measured in (a) is not greater than 40nsec. Adjust L5 to obtain best trailing edge.
- (j) Set COARSE OUTPUT to -25V, adjust C15 until overshoot just appears on leading edge.
- (k) Set COARSE OUTPUT to +50V. Adjust L4 to obtain the best leading edge, check that the rise time, measured as in (h) is not greater than 50nsec. Then adjust L6 for best trailing edge. NOTE: In this test, overshoot may not appear and, therefore, the inductors should be adjusted for fastest time of rise.

5. Double Pulse

- (a) Set function switch for double pulse operation.
- (b) Connect pre-pulse output to the trigger input of the oscilloscope.
- (c) Check on all COARSE WIDTH ranges, that with the FINE WIDTH at '1' the inter pulse period can be reduced to give a mark/space/mark ratio of approximately 1:1:1 before the second pulse begins to narrow.
- (d) Repeat (c) with FINE WIDTH at 10, check that the mark/space/mark ratio can be made 5:1:5 before the second pulse begins to narrow.

NOTE: It will be observed while checking on the 0.1μsec COARSE WIDTH range, that the first pulse is wider than the second by about 0.05μsec or less. This is due to the dissimilarity in shape of the pre-pulse and delayed pulse.

D.C. VOLTAGES

The typical voltages shown below were observed on a 20k Ω /V meter with the controls set as follows:

Output:	+5V	Fine Period:	10
Termination:	Internal	Delay:	Maximum
Coarse Period:	Trigger	Width:	Maximum

WAVEFORM GENERATOR

V1 pin 1	150V	V8 pin 2	8V
V1 pin 3	1.5V	V8 pin 1	14V
V1 pin 6	180V	V9 pin 7	160V
V1 pin 8	20V	V9 pin 3	14V
V2 pin 7	135V	Junc.R59/R60	32V
V2 pin 3	42V	V10 pin 3	12V
V3 pin 7	200V	Junc.R88/R89	10.5V
V3 pin 3	42V	V11 pin 1	11V
Junc.R24/R91	5V	V11 pin 2	-100V to -135V
V4 pin 7	200V	V11 pin 3	96V *
V4 pin 1	0.2V		
V5 pin 7	160V		
V5 pin 3	18V		
V6 pin 7	200V		
V6 pin 2	12V		
V6 pin 1	18V		
V7 pin 7	10V		
V7 pin 3	12V		
V8 pin 7	200V		

* NOTE

The voltage at pin 3 of V11 depends on the setting of VR6 and that of the Coarse Width S3.

POWER SUPPLY & OUTPUT STAGE

V1 pin 7	195V	V3 pin 7	115V
V1 pin 2	-10V	V3 pin 8	115V
V2 pin 7	200V	V4 pin 7	175V
V2 pin 2	1·6V	V4 pin 2	1·6V
V2 pin 3	11·75V	V5 pin 7	200V
V3 pin 1	-9·5V	V5 pin 2	-9·5V
V3 pin 2	-100V	V6 pin 2	-0·6V
V3 pin 3	-100V	Junc.C23/R64	310V
V3 pin 6	250V	Junc.C25/R69	340V

WAVEFORM GENERATOR

COMPONENTS LIST

RESISTORS

R1	33 Ω	1/4W	$\pm 10\%$
R2	330 Ω	1/4W	$\pm 10\%$
R3	6.8K	1/4W	$\pm 10\%$
R4	33 Ω	1/4W	$\pm 10\%$
R5	2.2K	1/4W	$\pm 10\%$
R6	2.2M	3/4W	$\pm 5\%$
R7	33 Ω	1/4W	$\pm 10\%$
R8	220K	3/4W	$\pm 5\%$
R9	33 Ω	1/4W	$\pm 10\%$
R10	4.7K	1/4W	$\pm 10\%$
R11	4.7K	1/4W	$\pm 10\%$
R12			
R13	33 Ω	1/4W	$\pm 10\%$
R14	33 Ω	1/4W	$\pm 10\%$
R15	1.8K	1.5W	$\pm 5\%$
R16	33 Ω	1/4W	$\pm 10\%$
R17	600 Ω	1/2W	$\pm 5\%$
R18	2.7K	3/4W	$\pm 5\%$
R19	33 Ω	1/4W	$\pm 10\%$
R20	220 Ω	3/4W	$\pm 5\%$
R21	470K	3/4W	$\pm 5\%$
R22	1.5K	1W	$\pm 10\%$
R23	33 Ω	1/4W	$\pm 10\%$
R24	330K	3/4W	$\pm 5\%$
R25	33 Ω	1/4W	$\pm 10\%$
R26	47K	3/4W	$\pm 5\%$
R27	6.8K	3/4W	$\pm 5\%$

WAVEFORM GENERATOR

R28	33Ω	1/4W	±10%
R29	8·2K	3/4W	±5%
R30	270K	3/4W	±5%
R31	33Ω	1/4W	±10%
R32	220Ω	1/4W	±10%
R33	1K	1/4W	±10%
R34	680Ω	1/4W	±10%
R35	33Ω	1/4W	±10%
R36			
R37	220K	3/4W	±5%
R38	8·2K	3/4W	±5%
R39	12K	3/4W	±5%
R40	33Ω	1/4W	±10%
R41	4·7K	1/4W	±10%
R42	33K	1/2W	±10%
R43	33Ω	1/4W	±10%
R44	1·5K	3/4W	±5%
R45	33Ω	1/4W	±10%
R46	680Ω	3/4W	±5%
R47	3·3K	3/4W	±5%
R48	33Ω	1/4W	±10%
R49	10K	3/4W	±1%
R50	33K	3/4W	±1%
R51	33Ω	1/4W	±10%
R52	1K	1/2W	±10%
R53	33Ω	1/4W	±10%
R54	2·2K	1/4W	±10%
R55	33Ω	1/4W	±10%
R56	33Ω	1/4W	±10%
R57	2·2K	3/4W	±5%
R58	6·8K	1/4W	±10%
R59	56K	3/4W	±1%
R60	12K	3/4W	±1%
R61	33Ω	1/4W	±10%
R62	270K	3/4W	±5%

WAVEFORM GENERATOR

R63	27K	3/4W	±5%
R64	33Ω	1/4W	±10%
R65	1·5K	3/4W	±5%
R66	33Ω	1/4W	±10%
R67	680Ω	3/4W	±5%
R68	1·5K	3/4W	±5%
R69	33K	3/4W	±5%
R70	33Ω	1/4W	±10%
R71	330K	3/4W	±5%
R72	68Ω	1/4W	±10%
R73	33Ω	1/4W	±10%
R74	33Ω	1/4W	±10%
R75	33Ω	1/4W	±10%
R76	1·2K	3/4W	±5%
R77	1K	3/4W	±5%
R78	33Ω	1/4W	±10%
R79	33Ω	1/4W	±10%
R80	1·5K	3/4W	±5%
R81	68K	1/2W	±10%
R82	33Ω	1/4W	±10%
R83	33Ω	1/4W	±10%
R84	33Ω	1/4W	±10%
R85	100K	1/4W	±10%
R86	820K	3/4W	±5%
R87	10M	3/4W	±5%
R88	220K	3/4W	±5%
R89	2·7K	3/4W	±5%
R90	10K	3/4W	±5%
R91	1·5M	3/4W	±5%

POTENTIOMETERS

VR1	10K	PLESSEY	TYPE E
VR2	100K	COLVERN	CLR/4001/11S
VR3	10K	WELWYN	P22
VR4	500Ω	WELWYN	P22

WAVEFORM GENERATOR

VR5	100K	COLVERN	CLR/4001/11S
VR6	100K	COLVERN	CLR/4001/11S
VR7	500Ω	WELWYN	P22
VR8	100K	COLVERN	CLR/4001/11S

CAPACITORS

C1	1μF	500V	PAPER	
C2	10pF	350V	VITREOUS	±10%
C3	·25μF	350V	PAPER	±20%
C4	·1μF	500V	PAPER	±20%
C5	·001μF	500V	CERAMIC	
C6	8μF	350V	ELECT.	
C7	·001μF	500V	CERAMIC	
C8	·1μF	500V	PAPER	±20%
C9	2-20pF	500V	TRIMMER	
C10	200pF		SIL. MICA	±1%
C11	·0022μF		SIL. MICA	±1%
C12	·022μF	500V	PAPER	±2%
C13	·22μF	250V	PAPER	±2%
C14	2 x 1 + 22μF	250V	PAPER	±2%
C15	15pF	350V	VITREOUS	±10%
C16	·1μF	500V	PAPER	±20%
C17	33pF	350V	VITREOUS	±10%
C18	·001μF	500V	CERAMIC	
C19	·1μF	500V	PAPER	±20%
C20	·100pF	350V	VITREOUS	±10%
C21	·001μF	500V	CERAMIC	
C22	·001μF	500V	CERAMIC	
C23	·001μF	500V	CERAMIC	
C24	·001μF	500V	CERAMIC	
C25	10pF + 2 - 20pF		TRIMMER	
C26	210pF		SIL. MICA	±1%
C27	·0022μF		SIL. MICA	±1%
C28	·022μF	500V	PAPER	±2%

WAVEFORM GENERATOR

C29	$\cdot 22\mu F$	250V	PAPER	$\pm 2\%$
C30	$2 \times 1\mu F + \cdot 22\mu F$	250V	PAPER	$\pm 2\%$
C31	$\cdot 5\mu F$	500V	PAPER	$\pm 20\%$
C32	$\cdot 001\mu F$		CERAMIC	
C33	$1\mu F$	250V	PAPER	$\pm 25\%$
C34	$\cdot 001\mu F$	500V	CERAMIC	
C35	$\cdot 001\mu F$	500V	CERAMIC	
C36	47pF	350V	VITREOUS	$\pm 10\%$
C37	$\cdot 001\mu F$	500V	CERAMIC	
C38	$\cdot 01\mu F$	500V	PAPER	$\pm 20\%$
C39	$\cdot 1\mu F$	500V	PAPER	$\pm 20\%$
C40	$10pF + 2-20pF$		TRIMMER	
C41	210pF		SIL. MICA	$\pm 1\%$
C42	$\cdot 0022\mu F$		SIL. MICA	$\pm 1\%$
C43	$\cdot 022\mu F$	400V	PAPER	$\pm 2\%$
C44	$\cdot 22\mu F$	250V	PAPER	$\pm 2\%$
C45	$1 + 1\mu F + \cdot 22\mu F$		PAPER	$\pm 2\%$
C46	33pF	350V	VITREOUS	$\pm 10\%$
C47	$\cdot 001\mu F$	500V	SIL. MICA	
C48	$\cdot 01\mu F$	500V	PAPER	$\pm 2\%$
C49	$\cdot 1\mu F$	250V	PAPER	$\pm 2\%$
C50	$1\mu F$	250V	PAPER	$\pm 2\%$
C51	$\cdot 1\mu F$	500V	PAPER	$\pm 20\%$
C52	$\cdot 001\mu F$	500V	CERAMIC	
C53	$\cdot 01\mu F$	500V	PAPER	$\pm 20\%$
C54	47pF	350V	VITREOUS	$\pm 10\%$
C55	$\cdot 001\mu F$	500V	CERAMIC	
C56	$\cdot 001\mu F$	500V	CERAMIC	
C57	$\cdot 001\mu F$	500V	CERAMIC	
C58	$\cdot 001\mu F$	500V	CERAMIC	
C59	$\cdot 001\mu F$	500V	CERAMIC	
C60	4.7pF	500V	CERAMIC	

WAVEFORM GENERATOR

VALVES

V1	ECC81	MULLARD
V2	EL822	MULLARD
V3	EL822	MULLARD
V4	E 180 F	MULLARD
V5	E 180 F	MULLARD
V6	E 180 F	MULLARD
V7	ECC81	MULLARD
V8	E 180 F	MULLARD
V9	E 180 F	MULLARD
V10	ECC81	MULLARD
V11	ECC81	MULLARD

RECTIFIERS

MR1	OA73	MULLARD
MR2	OA81	MULLARD
MR3	OA73	MULLARD
MR4	OA73	MULLARD

CHOKES

L1	50 μ H-80 μ H	SAA6696/L	-
L2	7 μ H	SAC9147/L	BLACK
L3	18 μ H	SAA9500/A	ORANGE
L4	18 μ H	SAA9500/A	ORANGE
L5	7 μ H	SAC9147/L	BLACK
L6	14 μ H	SAC9147/M	RED
L7	18 μ H	SAA9500/A	ORANGE
L8	31.5 μ H	SAC9147/S	GREEN

PLUGS

P1	12 WAY	MCMURDO	XP12
P2	RED	BELLING LEE	L378/4
P3	BLACK	BELLING LEE	L378/4

WAVEFORM GENERATOR

SOCKETS

SKT. 1	JS1 PF	FILMS & EQUIPMENT
SKT. 2	JS1 PF	FILMS & EQUIPMENT

TERMINALS

TER. 1	YELLOW	BELLING LEE L1001/1SB
TER. 2	BLACK	BELLING LEE L1001/1SB
TER. 3	BLACK	BELLING LEE L1001/1SB
TER. 4	WHITE	BELLING LEE L1001/1SB

SWITCHES

S1	4 POLE	7 WAY	N.S.F. TYPE DH.
S2	2 POLE	6 WAY	N.S.F. TYPE DH.
S3	4 POLE	6 WAY	N.S.F. TYPE DH.
S4	TYPESP103	WALTER INST.	PUSH TO BREAK
S5	S.P.S.T.		

POWER SUPPLY AND OUTPUT STAGE

COMPONENTS LIST

RESISTORS

R1	120K	3/4W	±1%
R2	8·2K	3/4W	±1%
R3	100K	3/4W	±1%
R4	33Ω	1/4W	±10%
R5	33Ω	1/4W	±10%
R6	560Ω	6W	±5%
R7	330Ω	1½W	±5%
R8	10Ω	1/4W	±10%
R9	110K	3/4W	±1%
R10	100K	3/4W	±1%
R11	33Ω	1/4W	±10%
R12	33Ω	1/4W	±10%
R13	10Ω	1/4W	±10%
R14	68K	3/4W	±5%
R15	100K	3/4W	±5%
R16	18K	3/4W	±5%
R17	33Ω	1/4W	±10%
R18	15K	3/4W	±5%
R19	6·8K	1/2W	±10%
R20	33Ω	1/4W	±10%
R21	56K	3/4W	±5%
R22	4Ω	1W	±5%
R23	390Ω	1W	±5%
R24	68K	3/4W	±5%
R25	22Ω	3/4W	±5%
R26	10Ω	3/4W	±5%
R27	82K	3/4W	±5%
R28	33Ω	1/4W	±10%

POWER SUPPLY AND OUTPUT STAGE

R29	33Ω	1/4W	±10%
R30	10Ω	1/4W	±10%
R31	33Ω	1/4W	±10%
R32	33K	3/4W	±5%
R33	1K	6W	±5%
R34	620Ω	6W	±5%
R35	390K	3/4W	±5%
R36	6·8K	1/4W	±10%
R37	100K	3/4W	±5%
R38	2·2M	1/4W	±10%
R39	150Ω	1/2W	±10%
R40	75Ω	3/4W	±1%
R41	75Ω	3/4W	±1%
R42	150Ω	3/4W	±1%
R43	33Ω	1/4W	±10%
R44	33Ω	1/4W	±10%
R45	600Ω	1½W	±1%
R46	1K	6W	±5%
R47	75Ω	3/4W	±1%
R48	150Ω	3/4W	±1%
R49	126Ω	3/4W	±1%
R50	600Ω	1½W	±1%
R51	1K	6W	±5%
R52	33Ω	1/4W	±10%
R53	500Ω	1W	±1%
R54	75Ω	3/4W	±1%
R55	39Ω	3/4W	±5%
R56	840Ω	1½W	±1%
R57	150K	3/4W	±5%
R58	68K	3/4W	±5%
R59	150K	3/4W	±5%
R60	220K	1/4W	±10%
R61	330K	1/4W	±10%
R62	2·2M	1/4W	±10%
R63	33Ω	1/4W	±10%
R64	10Ω	1/2W	±10%

POWER SUPPLY AND OUTPUT STAGE

R65	33 Ω	1/4W	$\pm 10\%$
R66	10 Ω	1/2W	$\pm 10\%$
R67	4.7K	12W	$\pm 5\%$
R68	1.5K	12W	$\pm 5\%$
R69	3.3K	12W	$\pm 5\%$
R70	4.7K	3/4W	$\pm 5\%$
R71	10 Ω	1/2W	$\pm 10\%$
R72	10 Ω	1/2W	$\pm 10\%$
R73	10 Ω	1/2W	$\pm 10\%$
R74	10 Ω	1/2W	$\pm 10\%$

POTENTIOMETERS

VR1	25K	WELWYN	P22
VR2	25K	WELWYN	P22
VR3	25K	WELWYN	P22
VR4	25K + 25K	COLVERN	CLR 4049/11S
VR5	25K	WELWYN	P22
VR6	25K	WELWYN	P22
VR7	25K	WELWYN	P22
VR8	25K	WELWYN	P22
VR9	25K	WELWYN	P22
VR10	10K	WELWYN	P22
VR11	25K	WELWYN	P22

BLOWER

FAN RANK PRECISION IND.

CAPACITORS

C1	680pF		VITREOUS	$\pm 10\%$
C2	.005 μ F	1000V	PAPER	$\pm 20\%$
C3	1 μ F	500V	PAPER	$\pm 20\%$
C4	8 μ F	450V	ELECT.	
C5	.1 μ F	500V	PAPER	$\pm 20\%$
C6	.5 μ F	500V	PAPER	$\pm 20\%$

POWER SUPPLY AND OUTPUT STAGE

C7	2 x 1 μ F	500V	PAPER	$\pm 2\%$
C8	2 x 1 μ F	500V	PAPER	$\pm 2\%$
C9	450pF		VARIABLE	
C10	·25 μ F	500V	PAPER	$\pm 20\%$
C11	·1 μ F	500V	PAPER	$\pm 20\%$
C12	100pF		VITREOUS	$\pm 10\%$
C13	33pF		VITREOUS	$\pm 10\%$
C14	3-30pF		TRIMMER	
C15	3-30pF		TRIMMER	
C16	·1 μ F	500V	PAPER	$\pm 20\%$
C17	·1 μ F	500V	PAPER	$\pm 20\%$
C18	·1 μ F	500V	PAPER	$\pm 20\%$
C19	·1 μ F	500V	PAPER	$\pm 20\%$
C20	100 μ F	450V	ELECT.	
C21	·1 μ F	500V	PAPER	$\pm 20\%$
C22	8 μ F	450V	ELECT.	
C23	32 μ F	450V	ELECT.	
C24	16 μ F	450V	ELECT.	
C25	16 μ F	450V	ELECT.	
C26	·1 μ F	500V	PAPER	$\pm 20\%$
C27	·1 μ F	500V	PAPER	$\pm 20\%$
C28	·001 μ F		CERAMIC	
C29	·001 μ F		CERAMIC	
C30	150pF		VITREOUS	$\pm 10\%$
C31	22pF		VITREOUS	$\pm 10\%$

VALVES

V1	EL822	MULLARD
V2	EL822	MULLARD
V3	ECC81	MULLARD
V4	EL822	MULLARD
V5	EL822	MULLARD
V6	ECC83	MULLARD
V7	150B2	MULLARD
V8	6080	MULLARD

POWER SUPPLY AND OUTPUT STAGE

RECTIFIERS

MR1	OA81	MULLARD	(Alt. OA71)
MR2, MR3,	80AS	PLESSEY	
MR4			

CHOKES

L1	1.1 - 2 μ H	BROWN	SAA7888/H
L2	0.9 - 1.6 μ H	BLACK	SAA7888/G
L3	2.3 - 5 μ H	RED	SAA7888/J
L4	6 - 13 μ H	GREEN	SAA7888/F
L5	3.4 - 7 μ H	ORANGE	SAA7888/K
L6	6 - 13 μ H	GREEN	SAA7888/F
L7	0.5 μ H	-	A9371
L8	0.5 μ H	-	A9371

FUSES

F1	3 AMP	BELLING LEE
F2	3 AMP	BELLING LEE

NEON INDICATOR

N11	G.E.C.	TYPE G
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LAMP

LP1	6.5V	0.3A	M.E.S.
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SWITCHES

S1	11 POLE 9 WAY	N.S.F.	TYPE DH
S2	MAINS	ON/OFF	
S3	INT/EXT		

MAINS SELECTOR PANEL

MS91	CT38
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TRANSFORMER

T1	CINTEL	29A3177
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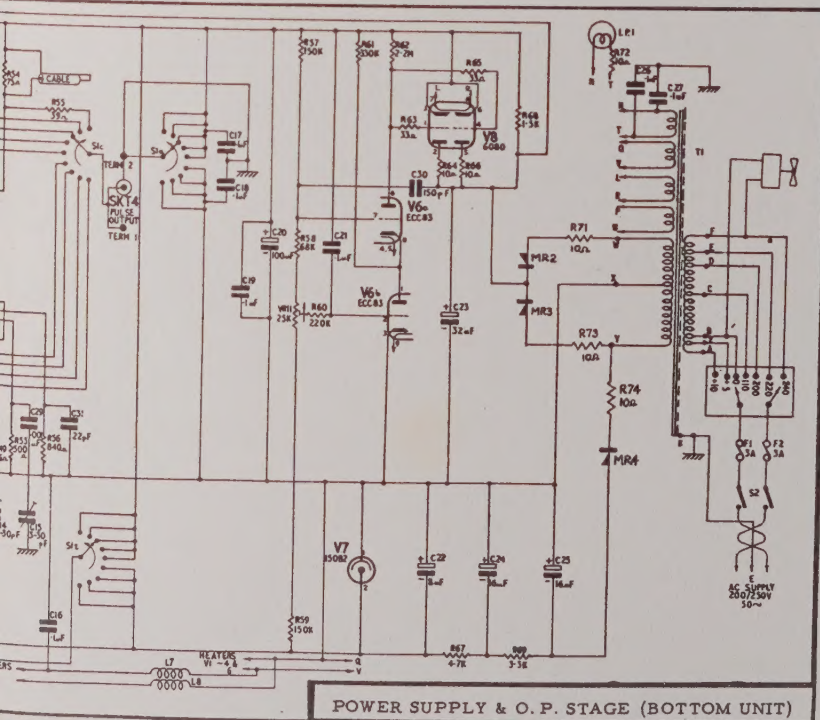
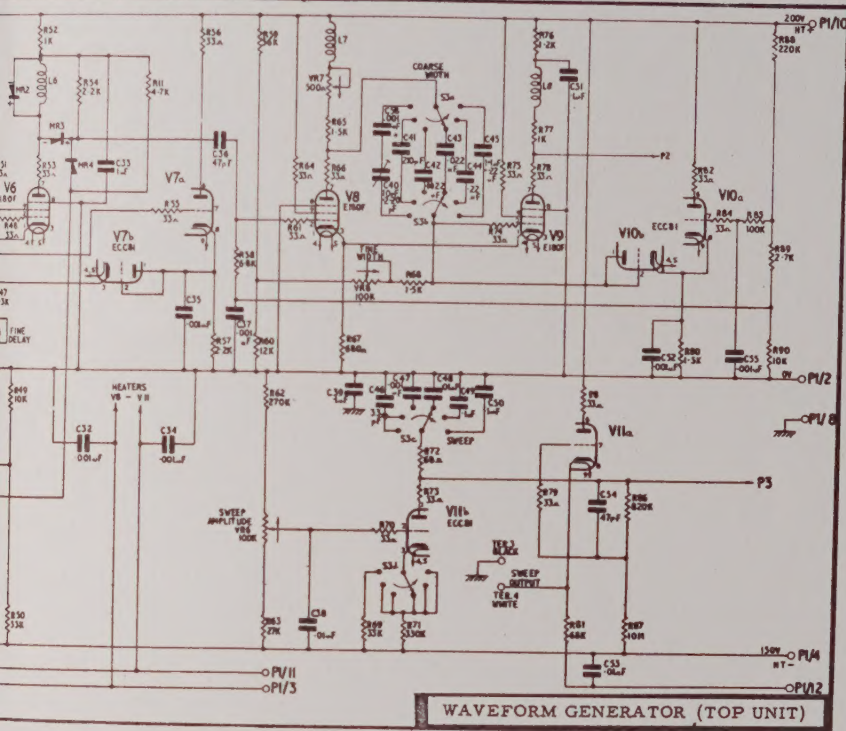
POWER SUPPLY AND OUTPUT STAGE

SOCKETS

SKT.1	12 WAY	MCMURDO	XS12
SKT.2	RED	B/L	
SKT.3	BLACK	B/L	
SKT.4	J S 1 FF	F & E	

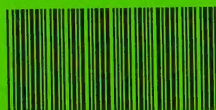
TERMINALS

TERM 1	RED	B/L	1001/1SB
TERM 2	BLACK	B/L	1001/1SB





MP MASTER



MA23841